COMPONENT-BASED ANALYSIS AND DESIGN OF ROUTING PROTOCOLS FOR MOBILE AD HOC NETWORKS[1]

I-Jeng Wang[2]
Lotfi Benmohamed
Steven D. Jones

Johns Hopkins University
Applied Physics Laboratory

Chunyue Liu

Dept. of Computer Science
Graduate Center of City
University of New York

Tarek Saadawi

Dept. of Electrical
Engineering, City College
and Graduate Center of City
University of New York

In this paper, we present a *component-based* framework for analysis and design of routing protocols for mobile ad hoc networks (MANET). This framework defines a common set of functional components for a MANET routing protocol under which a protocol can be designed and analyzed at the component basis. Each MANET routing protocol is designed and optimized to address the *entire* routing problem that consists of many dimensions. To tackle the significant challenges arising in mobile ad hoc wireless networks, each protocol is a complicated piece of software with many intertwined components. As a result, the *protocol-based* approach, which designs and analyzes each protocol as a *whole* to address each unique routing performance requirement, provides limited insight into key aspects of protocols. In addition, careful examination of existing protocols shows that many protocols share fundamentally the same mechanisms/algorithms for common functions in support of routing (perhaps with different minor optimization or fine-tuning to achieve specific performance improvements). These overlaps further increase the difficulties of protocol-based comparison and analysis. Finally, each attempt to design a new protocol to address new technical challenges might imply development of the entire routing function that in many cases duplicates past efforts and reproduces similar results at the component levels.

Many networks designed to support current or future Army operations are inherently MANET-type networks, for example the Future Combat Systems. To support dynamic routing in these MANETs operating over a wide spectrum of networking and environmental conditions, the protocol(s) needs to dynamically configure its routing strategies/mechanisms in response to either anticipated or unexpected shifts in these conditions. The required reconfiguration can exceed what any single *adaptive* protocol can achieve while maintaining satisfactory performance. The proposed component-based framework will enable us to design, optimize, and adapt each component in a protocol in

---

[1] Prepared through collaborative participation in the Communications and Networks Consortium sponsored by the U. S. Army Research Laboratory under the Collaborative Technology Alliance Program, Cooperative Agreement DAAD19-01-2-0011. The U. S. Government is authorized to reproduce and distribute reprints for Government purposes notwithstanding any copyright notation thereon.
[2] Corresponding author; Johns Hopkins University Applied Physics Laboratory, Laurel, MD 20723; Tel: 240-228-6204; E-mail: I-Jeng.Wang@jhuapl.edu.

Report Documentation Page

Form Approved
OMB No. 0704-0188

1. REPORT DATE **00 DEC 2004**	2. REPORT TYPE **N/A**	3. DATES COVERED **-**
4. TITLE AND SUBTITLE **Component-Based Analysis And Design Of Routing Protocols For Mobile Ad Hoc Networks**		5a. CONTRACT NUMBER
		5b. GRANT NUMBER
		5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)		5d. PROJECT NUMBER
		5e. TASK NUMBER
		5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **Johns Hopkins University Applied Physics Laboratory; Dept. of Computer Science Graduate Center of City University of New York**		8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)		10. SPONSOR/MONITOR'S ACRONYM(S)
		11. SPONSOR/MONITOR'S REPORT NUMBER(S)
12. DISTRIBUTION/AVAILABILITY STATEMENT **Approved for public release, distribution unlimited**		
13. SUPPLEMENTARY NOTES **See also ADM001736, Proceedings for the Army Science Conference (24th) Held on 29 November - 2 December 2005 in Orlando, Florida.**		
14. ABSTRACT		
15. SUBJECT TERMS		

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT **unclassified**	b. ABSTRACT **unclassified**	c. THIS PAGE **unclassified**	**UU**	**2**	

Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std Z39-18

response to diverse operating conditions and performance requirements. The component-based adaptation will incur significantly less disruption and degradation than an approach based on switching of the entire protocol. For example, we can adapt route discovery in response to the changes in network connectivity (from sparse to dense) instead of switching from one protocol to the other (for example, AODV to DSR).

To establish the component-based framework, we first define a set of common function components necessary to support the routing function in MANETs. These building blocks for routing include *Route Information Representation*, *Route Determination/Selection*, *Packet Forwarding*, *Neighbor Discovery and Maintenance*, *Route Information Initialization*, *Dynamic Route Management*, *Failure Response*, and *Route Discovery*. For each component, we characterize the space of possible mechanisms/algorithms to support its designated functions. Note that this component-based characterization of protocols leads to a rich taxonomy that is much distinct from the popular proactive-versus-reactive (or on-demand) taxonomy. In fact, we can show that the popular twofold model (even with the so-called hybrid protocols) encompasses only a small subset of all possible designs for MANET routing defined by the proposed framework. To illustrate how each component can be characterized to define a complete routing protocol, we present mappings of four existing protocols, including AODV, DSR, OLSR, and TBRPF, to their corresponding component-based definitions. Based on the mappings, we compare and contrast these four protocols at the component-level basis.

As an initial effort toward the complete component-based protocol designs, we present results on designs of two components: the Route Information Initialization and the Dynamic Route Management. We demonstrate that by redesigning these components we can potentially achieve performance improvements and much richer behaviors for existing protocol designs. We accomplish this task by taking two existing on-demand protocols, AODV and DSR, and redefining the two selected components for each protocol. The resulting "protocols" represent a large class of protocol designs that is inherently traffic-dependent and is both on-demand and proactive (or neither in a "pure classification"). For instance, considering the dynamic route management component, an implementation that uses a static time-out period T (after which a discovered route expires) would not be able to perform well under varying traffic conditions. A shorter T results in larger overhead due to more frequent route discovery activity whereas a larger T results in extra delay (incurred when new traffic to a destination arrives and no route is cached due to traffic being idle for a time interval longer than the time-out period T). We present in this paper one alternative implementation for this component that achieves a good tradeoff between control overhead and packet delivery delay. We realize that any attempt to decompose complex software like routing protocols will lead to unavoidable loss of generality. Poor definition of components and their interface can also result in possible performance degradation. However, we believe that the benefits of proper functional decomposition will outweigh these drawbacks.[3]

---

[3] The views and conclusions contained in this document are those of the authors and should not be interpreted as representing the official policies, either expressed or implied, of the Army Research Laboratory or the U. S. Government.